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PHOTOGRAPHIC MEASURES OF ACCOMMODATIVE-CONVERGENCE*

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HISTORICAL INTRODUCTION

The association between accommodation and convergence has been known for many years, but there have been numerous conflicting opinions expressed concerning it. Donders[6] pointed out in 1864 that a connection exists between accommodation and the convergence of the visual lines and also stated that Porterfield in 1759 and Mueller in 1826 had also directed attention to this problem. Porterfield and Mueller assumed, however, that a definite convergence is necessarily attended with a definite accommodation and no other. They believed that the limits of convergence were set by the near and far points of accommodation. Donders following Volkman showed that there is no such close relationship between accommodation and convergence by the simple expedient of placing lenses and prisms before a subject's eyes and demonstrating that he was still able to obtain clear single binocular vision. Donders also plotted curves showing the relative range of accommodation and convergence.

Most investigators agree that accommodation normally acts as a positive stimulus to convergence. On the other hand, some investigators feel that there is little relationship. After reviewing the literature on eye movement studies by Javal, Huey, and others, Fox[7] concludes, "Our comment would be that they seem to indicate that accommodation has little to do with binocular fixation and binocular fusion." Haessler[8] even goes so far as to conclude from his results, "The data are at varience with the belief that the impulse to accommodate is associated with increased convergence. However, there is nothing in the study to explain the paradox." The data which Haessler presented were taken from 96 subjects. The amount of prism base-in to diplopia was measured at 5 m., 50 cm., 33 cm., and 25 cm., and it was found that the amount of base-in prism that the subject could overcome increased as the accommodation

*An abridgment of the material presented before the American Academy of Optometry at Chicago, Ill., August 25, 1936.

increased, i.e., as the fixation point was brought nearer to the eyes. This finding caused Haessler to conclude that, "accommodation is a stimulus to divergence or an inhibition to convergence."

The falacy of Haessler's argument has been shown by Pascal[17] and Ludwig[13]. Pascal points out that prism divergence is the resultant of two forces, (1) accommodation restraining the relaxation of convergence, and (2) fusion forcing relaxation of convergence. Ludwig also shows from Haessler's data that the divergence was actually less than if there had been no relation at all, i.e., when the actual position of the eyes was considered rather than the abduction reading. Haessler's data show that accommodation affects divergence negatively rather than in a positive way.

Laurence[12] has pointed out that accommodation and convergence are intimately associated and that either function can be more easily exerted with the other, and it is difficult for one to be exerted without the other. Sheard[25] has also made extensive studies of this problem and has arrived at a similar conclusion.

Tait[29] made an extended study of the reciprocal relation between accommodation and convergence. In one investigation he observed 500 subjects between the ages of 10 and 40 years, and his results support Helmholtz'[9] theory of a true association relationship between accommodation and convergence built up during the early years of life. Tait found evidence to show that there is a reflex relationship between these two functions, reciprocal and associative in nature, in which either can be conceived as the primary stimulus and the other as the response. He also found that the amount of convergent-accommodation is proportional to the amount of accommodative-convergence as shown by a positive correlation between them.

Pollack[21] believes that accommodation and convergence are separate autonomous functions, but he believes, with Tait, that there is a reflex relationship between the two. This relationship, Pollack believes, is explainable on the basis of the theory of conditioned reflexes, and he explains anomalies of the accommodative-convergence relationship on the basis of conditioned stimulations and inhibitions.

Tait[30] has also pointed out that accommodation is not the only factor which may act as a conditioned stimulus to convergence. He made a group of subjects emmetropic and measured phorias through different plus additions and found that the decrease in accommodative-convergence was not proportional to the accommodative activity. Tait concludes, therefore, that "proximal convergence" should be added to the sources of stimuli responsible for reflex convergence.

The condition of heterophoria has been recognized by clinical workers for years and according to Maddox[14] was treated by Braily as early as 1880. Numerous studies of the problem have been made to determine norms. Weymouth[31] and his co-workers at Stanford University reviewed the findings of Duane, Theobald, Howe, Maddox,

Sheard and others, and found that their own experimental results agreed in general with the data of other observers. They found a normal physiological exophoria of 5-6△ at the reading distance. More recently Tait[29] has obtained norms which also corroborate these earlier findings. ings.

Numerous methods have been devised to measure heterophoria, e.g., Maddox rod, simple displacing prisms, bi-prisms, and the Maddox wing test. All of these methods are either wholly or partly subjective. Zeis[32] at Leipzig, criticizes methods which are based on an alinement of foveal and extra-foveal images. To overcome this, Zeis and his coworkers have devised a clinical instrument involving photography. The subject wears a green glass over one eye and a red glass over the other. By suitable adjustment of the instrument, which has a complex optical system, he brings the red and green images of a white light source into coincidence. When this is accomplished, a photographic record of the position is made. This method has given semi-objective phoria measures using the two foveas as the points of reference.

A. J. Esdaile in England also devised a semi-objective method to measure heterophoria.† A graph of the ocular movements is recorded by the patient. "The act of graphing is actually induced by the mental projection through the right eye of a moving object seen by the left. A fixing prism is rotated by a motor before the left eye . . . The turning of the prism at a carefully controlled speed causes the luminous disc to describe a circle, but the circular movement is not registered by the left eye actually looking at it, but by the right eye, and it is seen upon a black screen . . . " The left eye is prevented from seeing the screen by a mirror in which the rotating light is seen. The path taken by the revolving image is followed by a ring (seen by the right eye) operated by the patient who endeavors to keep the ring around the light. Several trials are taken and then the graphing apparatus is brought into use, and a record is obtained. Another graph is then taken for the other eye. The relative positions of the two graphs on the chart give a determination of the binocular balance in different meridians and the effect of accommodation can be readily shown.

STATEMENT OF THE PROBLEM

Photographic determinations of convergence and divergence have been made by Judd,[11] Dodge,[4] and Clark,[3] showing the "normal" processes involved in changing fixation between two points placed at different distances in space, but as far as the writer has been able to determine, no strictly objective photographic measures have been made of convergent and divergent movements which result from the stimulus of accommodation. It was the initial purpose of this investigation to study subjects

†The data on this instrument were obtained from an original manuscript and patent papers obtained through the courtesy of Mr. E. G. Guyatt and Mr. Esdaile's son in London. A brief description is also given in the reference to Roche's work on nystagmus (23).

with "normal" binocular balance and compare their accommodative-convergence and divergence with the convergence and divergence which occurred when both eyes changed fixation between two points in space.

The second objective was to determine the possibilities of eye movement photography as an objective method of measuring heterophoria by comparing the photographic data with data obtained by routine clinical procedures.

APPARATUS AND PROCEDURE

The subjects used in this investigation were students in the University of Southern California. There were 16 men and 4 women. The age range was between 18 and 28 years. The range of interpupillary distances was 60-69 mm., and the binocular balance ranged from 0-5△ exophoria at 13 in. and 0-1△ at 244 cm. Four of the subjects were left eyed and the others were right eyed by Miles V-scope test.[16]

The eye movements of the subjects were photographed with a camera which recorded the vertical and horizontal movements of both eyes. The subjects changed their fixation between a near and distant fixation point keeping time with a metronome beating 70 times per minute. The near fixation point was placed 33 cm. from the subjects' eyes. It consisted of a black dot 0.5 mm. in diameter placed in the center of a square formed by two horizontal and vertical lines which extended beyond the limits of the square. The length of the lines was 7 mm., and the square formed by them was 1.5 mm. on each side. The fixation object was illuminated by a 60 watt lamp placed 8 in. above and slightly in front of it. The second fixation object was viewed in a mirror placed in such a position that the virtual image was 244 cm. from the subjects' eyes. The fixation object was similar to the first one. The point was 1.5 mm. in diameter, the vertical and horizontal lines were 10 mm. long, and the square was 4 mm. on each side. This was mounted on a circular paper screen 3.5 cm. in diameter, and was illuminated from behind by a 15 c.p. 6-8 volt lamp.

The experimental procedure was as follows: The phorias were first measured at 33 cm. and at 244 cm. by two three diopter displacing prisms placed in a frame held by the subject. The test letters were on charts containing an arrow above a line of letters. The prisms caused vertical diplopia, and the subject merely reported the position of the arrow which indicated the phoria directly. The visual acuity of the two eyes was then tested at the same distances to insure equal vision in both eyes. Any subjects showing unequal vision at either distance were not used in this study.

Immediately following these tests the eye movements were photographed while the subject changed fixation between the two objects. The mirror was first adjusted so that the image of the distant object was almost directly under the near fixation point for one eye, and then for the second trial it was changed so that the image was directly alined for the other eye. This required that first one eye and then the other would

make the larger convergent and divergent movements and permitted a comparison of the two eyes. The eye which was lined up will be called the "alined eye."

The subjects took several practice trials while the experimenter observed the eyes to be sure that the subject understood what was desired. In order to determine the influence of accommodation on convergence, a black card was placed in such a position that the "alined eye" could see both near and distant fixation points, but the "non-alining eye" could see neither. The position of the card was carefully marked, and it was then removed until later in the test.

After the practice trials the camera was focused, the metronome started and the subject began to change fixation between the two points, but the actual recording was not begun until the subject had made at least 5 or 6 convergent and divergent movements. After the subject had completed about 12 interfixation movements, the camera light was cut off momentarily giving a time mark on the film, and at the same time, the card was inserted into its proper position, and the subject continued changing his fixation between the two points. The fixation was, however, accomplished with but one eye, i.e., records of accommodative convergence were obtained. After a brief rest period, the same procedure was repeated for the other eye. Immediately after each trial, the subject was asked if he was able to get clear and single vision for each fixation. The records were discarded if the subject was unable to accomplish this.

RESULTS

1. *Binocular convergent movements.* The photographic records were first examined to determine the characteristic binocular behavior of this group under the conditions of this experiment. An outstanding feature of the behavior of the eyes was the marked variability exhibited on successive movements between the same fixation points in space. This is similar to the results reported by Judd,[11] Dodge,[4], Jasper,[10] and Clark[3] in the previous studies. Sometimes the first part of the movements between the points would be rapid and the later slow, and sometimes the reverse would be true. At times the eyes would over-converge and then make divergent movements before the fixation was completed. Marked binocular discrepancies were present continually; at times one eye would remain fixed while the other moved.

The general method of movement was also variable in another way. On some occasions the eyes would converge or diverge constantly from the beginning to the end of the movement, at other times the eyes would make a saccadic movement followed by a slower one to complete the fixation. As many as 3 separate saccadic movements were made to complete a fixation. These saccadic movements were not the same in both eyes and were usually made between slower movements.

The eyes also showed two other types of anomalous movements. On several occasions the eyes would assume a certain fixation position

for 3 or 4 successive fixations and suddenly for no apparent reason would shift to another position. This in turn would be held for a series of fixations. The other type of anomalous movement was that of associated movements prior to convergent or divergent movements as have been previously reported by Judd,[11] Jasper,[10] and Clark.[3] On a few occasions the reverse of the associated movements would occur, i.e., the "alining eye" would be forced off of the fixation point to make a convergent or divergent movement. The associated movements were so large in some cases that the "alining eye," i.e., the eye which normally should make only a vertical movement, would actually be the eye to make the final convergent or divergent movement.

The time required to complete the convergent and divergent movements was determined by measuring, with dividers, the point at which the lines indicating horizontal movements reached parallelism. In some cases it was difficult to determine this point exactly, and the error was probably as much as 1/25 second in some cases where the movement was slow. A total of 686 movements was measured. A comparison was made of the time required to complete the movements with the dominant and non-dominant eyes as determined by the Miles V-scope technique.[16] The data are summarized in Table I.

TABLE I.

Average Time in 1/25 secs. to Complete Movement

	Convergence	Divergence
Dominant eye	10.58±2.89	18.18±3.61
Non-dominant eye	10.97±3.34	17.59±2.87
D	0.39	0.59
D/σ diff.	0.39	0.59

These data show no significant difference in the responses for the dominant and non-dominant eyes. For this reason the data for both eyes were grouped to compare convergence and divergence time. The average time to complete the divergent movements was 17.9±2.2/25 secs., for the convergent movements, 10.8±3.1/25 secs., D=7.1; D/σ diff.=5.1, showing that the divergent movements were approximately 70% slower and that the difference is statistically significant. Convergent movements as long as 1 second occurred, and some were as short as 2/25 seconds. Divergent movements required as long as 1.5 seconds and were completed in as short a time as 10/25 seconds. These times are similar to those found by Judd,[11] and Dodge,[4] when the differences in fixation distances are considered.

The variability of the fixation movements was compared for the dominant and non-dominant eyes and no significant differences were found. The non-dominant and dominant eyes were also compared to determine any differences in making incongruous associated movements prior to convergent or divergent movements. There was no reliable difference. The dominant eye made an associated movement away from the

fixation point, i.e., was "pulled from" the fixation point by the non-dominant eye 85% of the time, while the dominant eye only "pulled" the non-dominant eye off 78% of the time.

The extent of these associated movements was also determined. The average amount that the dominant eye was "forced off" the fixation point was $3.94 \pm 1.33°$, while the non-dominant eye was "forced off" of the fixation point by the dominant eye $3.76 \pm 1.73°$. The difference of $0.18°$ was not statistically significant.

These data seem to indicate that the "sighting eye" does not have a tendency to dominate the other eye in causing incongruous movements. A similar thing was also found if all of the right eyes were compared with all of the left eyes. These data appear to differ with Jasper's[10] results in which he found "a tendency to more right lead patterns on the part of left handed S's and the tendency to more left lead patterns on the part of the right handed S's." In order to directly compare Jasper's results with those of this experiment, the hand used in writing was determined for each of the subjects. It was found that all but one of the subjects were right handed on the basis of this criterion. The right handed subjects showed no tendency to dominate with either eye. The right eye made associated movements following the left 84% of the time, and the left eye made similar movements 77% of the time. The one left handed subject made these associated movements 100% of the time for both eyes. It would appear from these data that in the process of convergence and divergence under the conditions of this experiment neither eye would tend to dominate consistently. The small difference shown was, however, in the same direction indicated by Jasper's results. It should be emphasized that Jasper's experimental set-up was designed to have the eyes working at or near a "breaking point" as far as binocular vision was concerned, whereas in this experiment, the situation approximated the conditions ordinarily maintaining in normal binocular convergent and divergent movements.

These results also throw into question the view held by some investigators, e.g., Schoen[24] that: "One of the basic principles which must be considered in any discussion of ocular asymmetry is the fact that the dominant eye assumes leadership in the act of binocular fixation by directing its visual axis to the object of regard. This initial step of binocular activity is followed by an adjusting movement of the non-dominant eye in order to permit the stimulation of corresponding retinal points."

It is true that a subject may be *forced* to choose one eye by one of the numerous tests of dominance (e.g., V-scope, peep-hole, pencil test, Mills converging test, duction tests). In such situations most subjects will choose one eye quite consistently for each test. To assume, however, that the eyes act in a similar manner in normal binocular vision is quite another matter, and on the basis of these photographic results, it would appear that such a phenomenon should be seriously questioned. In regard

to Jasper's method of forcing a choice between eyes by making movements so fast as to eliminate binocular vision, a similar thing maintains, and on the basis of a cerebral dominance, the neurological relation between handedness and eyedness is not clear when one considers the partial decussation of both the sensory and motor fibers of the eye (20).

The variation in the final position of the eyes for both near and distant fixation points was determined. Fixations, with the right and left eyes, were considered together as no significant differences were found between them. This variation was determined by measuring the final position of the eyes for each fixation and determining the deviations from the average for each subject. At 33 cm., these deviations averaged 17.2 ± 14.4 minutes, and at 244 cm., 16.2 ± 10.2 minutes, showing no reliable difference between the variability at the near and far fixation distances as was previously found in stereoscopic vision.[3] The average maximum variation for the subjects was also determined and was found to be 48.5 ± 26.9 minutes at 33 cm., and 42.2 ± 19.5 minutes at 244 cm. The largest variation during binocular fixation at the near point in any subject was $7\triangle$ and at the far point $4.8\triangle$, i.e., the eyes varied as much as $7\triangle$ in their final fixation position from one fixation of the same point to another in spite of the fact that single vision was reported subjectively. These findings agree with the previous findings of Peckham[18] and Clark[3] in indicating marked variations from the stimulation of "corresponding retinal points" during single binocular vision.

2. *Accommodative-convergence.* In general, the accommodative convergent movements were similar to the binocular convergent movements, especially in regard to the variability. There were, in all subjects, definite differences in the final position assumed by the non-fixing eye. Associated movements occurred prior to accommodative-convergent movements as they did in binocular fixation, although not as frequently. Marked changes in the position of the non-fixing eye occurred. The general method of movement was relatively consistent and tended to be a regular movement from the initial to the final position.

There was no statistically reliable difference between the times required to complete the movements during fixation by the right and left eyes (D/σ diff. in each case was less than 0.50), so both the right and left fixations were considered together. The results are tabulated and compared with data for binocular fixation in Table II.

These data show that accommodative-convergence takes less time than accommodative-divergence and the difference is statiscally significant. These results also show that the differences between the times required by binocular convergence and accommodative convergence are not statistically significant, although the average binocular adjustments were more rapid for both convergent and divergent movements. The maximum time required for accommodative-convergence was 30/25 secs., the minimum 4/25 secs. For accommodative-divergence, the maximum time was 38/25 secs., and the minimum time was 4/25 secs.

TABLE II.

Table Showing the Time in 1/25 secs., Required to Complete Binocular and Accommodative Convergent Movements

	Convergence	Divergence	D	D/σ diff.
Accommodative	14.6±4.6	19.9±4.1	5.2	3.0
Binocular	10.8±3.1	17.9±2.2	7.1	5.1
D	3.8	2.0		
D/σ diff.	2.2	1.1		

Associated movements prior to convergence or divergence occurred less frequently than in normal binocular fixation, i.e., the dominant eye was "forced" off of the fixation point by the non-dominant eye 39% of the time while the non-dominant eye was so affected 25% of the time. These associated movements were quite equally distributed between convergent and divergent movements, 54% occurred during divergence and 46% occurred during convergence.

The average variation in the final position is summarized and compared with binocular findings in Table III.

TABLE III.

Variability in the Final Position of the Eyes After Successive Accommodative Convergence Movements as Compared with Binocular Variations

Fixation	At 33 cm.	At 244 cm.
Monocular	28.4±11.6′	19.6±12.1′
Binocular	17.4± 4.4′	16.2±10.2′
D	11.0′	3.4′

The data include both right and left fixations as no significant difference was found between them. No statistically significant differences were found in comparing near and far fixations or in comparing binocular and monocular fixations.

The records were also examined to determine the final position of the eyes during accommodative-convergence as compared with normal binocular convergence. The average position of the eyes was determined for both 33 cm. and 244 cm., during binocular fixation, and the same was done for monocular fixation. As no significant differences were found between right and left fixations, both were considered together. The average binocular fixation was used as a base, and the average monocular variations were measured from it. These averages gave a measure of the position assumed by the eyes when binocular vision was prevented in a way similar to the common "cover test." That is to say, by these data one could objectively measure the subject's heterophoria under more or less "normal" conditions of vision.

At 244 cm., 19 of the 20 S's showed a greater tendency toward esophoria than was shown by the test with displacing prisms. The average tendency toward esophoria was 2.0±0.9△. The one subject showing

more exophoria indicated it to the extent of 0.4△. Aside from the fundamental differences in the tests there is probably another important reason why more esophoria was shown during the photographic situation. The test object for the prism test was quite large, requiring only a minimum of accommodation, whereas the test object used during photography was small and required accurate accommodation which would tend to cause more esophoria. The range in differences was from 0.3 to 4.6△.

A similar comparison for the near fixation point indicated that there was no significant tendency toward esophoria or exophoria. The average for the 20 S's was 0.2△ more exophoria. The individual deviations were, as might be expected, quite high. The average deviation from the measurements with the prisms was 2.6△ with a range from 0.2 to 5.8△. This range, although considerable, would probably not appear as significant if compared with individual variations on successive measurements using the same method. Such a study is being carried on by Dr. R. J. Beitel, Jr., and his results may tend to indicate whether these variations are as great as they seem. Of course from a practical point of view, deviations less than 1△ can be disregarded as negligible. These results were taken from the average of several trials for each subject. The variation around this average was also quite considerable for each individual. This variation ranged from 0-5△ and can be compared with the common oscillation present in the near phoria test. The differences between these two methods of determining heterophoria are no greater than those found by Swan[28] in comparing phoria measurements made using displacing prisms and Maddox rod. The average deviation determined from Swan's raw data show an average deviation of 2.7△ for 53 S's. Although Swan's results may not be directly comparable to those of this study because he made no attempt to select his cases, a comparison shown in Table IV indicates marked similarities.

TABLE IV

Table Comparing the Deviations in Phoria Measures—Maddox Rod vs. Displacing Prisms (Swan), and Displacing Prisms vs. Photography

Deviations in Prism Diopters	Prisms Photography		Prisms Maddox Rod	
	N	%	N	%
0-0.9	5	25	16	31
1-1.9	2	11	5	9
2-2.9	3	16	7	13
3-3.9	4	21	3	5
4-4.9	3	16	11	21
5-5.9	2	11	5	9
6 and over	0	0	6	12

These results would seem to indicate that such an objective photographic method of measuring heterophoria and accommodative convergence may have some clinical application. A priori it would seem rea-

sonable to assume that such a photographic method would more nearly approximate the conditions occurring in normal vision. This might give valuable clinical data and indicate reasons why one person with high heterophoria may have ocular discomfort and another will not. This would also eliminate Zeiss'[32] objection to phoria measurements made by the stimulation of foveal and extra-foveal areas. A study of cases having high binocular imbalances would be of value.

3. *The vertical component of the movements.* The vertical component of movement was found to be variable from one interfixation to another. The eyes showed a marked tendency to "over shoot" the mark in the vertical meridians as was found in a study of stereoscopic vision.[3] These "over shots" were as large as 9△ in some cases, but the complete movement was made in as short a time as 8/25 secs. The vertical component of the movement was sometimes made in one saccadic movement, but it sometimes required as many as 3 saccadic movements. The average time to complete the movement during binocular fixation was $3.7 \pm 2.2/25$ secs., and for the monocular fixation, $3.2 \pm 2.3/25$ secs. This average time included the time to make vertical corrective movements. It can be seen by comparing these data with the horizontal component of movement that, on the average, the eyes completed it in about ¼ of the time required to complete the convergent and divergent component. Considering the 2 eyes together, they moved down and converged for about 3/25 secs., and then continued to converge or diverge from 11 to 18/25 secs. These were, however, more or less random vertical movements associated with the continuing convergent or divergent movements.

SUMMARY AND DISCUSSION

The eye movements of twenty University students were photographed to determine the characteristics of "normal" convergence and accommodative-convergence. An examination of the results disclosed the following findings:

1. Wide individual differences were found in the behavior of the two eyes as well as in successive performances of the same individual. This was true of both binocular and accommodative convergence.

2. Marked variations from the stimulation of "corresponding retinal points" were present during single binocular vision. These variations were as large as 7△.

3. More time was required to complete divergent than convergent movements. This was true of both binocular and accommodative-convergence.

4. No statistically reliable difference was found between the time required to complete binocular and accommodative convergence.

5. Associated movements occurred prior to correct convergent or divergent movements during both binocular and accommodative convergence, but they were more frequent during binocular convergence.

6. For a wide variety of factors considered, there was no significant difference between the behavior of the dominant and non-dominant eyes. There was also no significant relation found when handedness was considered.

7. The photographic records gave objective measures of heterophoria which showed no greater deviation from the usual prism test than was found by Swan comparing the results of the Maddox rod and the prism tests.

8. There were also considerable variations in the vertical components of movement upon successive repetitions of the same movements.

These results throw some light on several theoretical and practical problems in physiological optics. One problem is: Which begins first, accommodation or convergence? Measures of accommodation time have been made by Banister and Pollack.[1] The average time for 2 S's to accommodate 2.25 D., was 0.57 secs. This is comparable to our own accommodative-convergence time of 0.58 sec., for a slightly greater amount of accommodation, and greater than the average binocular convergence time which was 0.43 sec. for 2.59 D. However, as was mentioned above, the difference between the monocular and binocular finding is not statistically reliable so it would appear probable, pending the measurement of accommodative times for a larger number of subjects, that accommodation and convergence times are practically the same and begin and end very close to the same time. The finding of variability in convergence also points to the probability of similar variations in accommodation during fixation as Sheard suggested some 25 years ago.[26] Some objective measure of accommodation would throw more light on this problem.

The suggestion has been made by Dolman[5] and more recently by McAndrews[15] that, in taking phoria measurements, the Maddox rod should always be placed over the non-dominant eye and that correcting prisms should also be placed before the non-dominant eye. It would seem that the latter statement, particularly, would be invalid on the basis of these experiments as no marked differences were found in the behavior of the two eyes. That is to say, these results seem to indicate that, in practical work, prisms may be placed over either eye. There are, of course, other reasons to substantiate this.

The data of this experiment also suggest that eye movement photography may be used as a test of monocular malingering. This could be done by comparing the behavior of blind eyes with the data of this experiment and the criteria would be purely objective.

The photographic method may also have a practical application in showing why some individuals with high heterophoria are relatively comfortable whereas others with lower defects are uncomfortable. A similar study of high binocular imbalances should give valuable data on the problem of binocular vision.

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PROCEDURE FOR ANALYZING CONVERGENCE AND ITS SUPPORTING FUNCTIONS*

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INTRODUCTORY

When Dr. Melvin first invited me to present this paper, I hesitated; first, because of the simplicity of the subject; second, because of my inability to present the subject in an interesting manner. However, after several letters requesting further information on this particular procedure, I decided to explain it before this academy to the best of my ability.

This procedure will not be of interest to those men who understand fully all about convergence. Neither will it be of interest to the men who are completely satisfied with their own technique. It will interest only the men who are in the front line trenches, so to speak, and must stand or fall upon their ability to make their patients comfortable—men who will take the two extra minutes necessary for this procedure.

It will not work perfectly on every case, but we believe that with the proper application it is a very valuable aid in the large majority of those border-line cases that cause us so much difficulty.

We shall try to discuss in this paper only those functions or subjects that are directly connected with or have a bearing upon the subject of convergence.

On page 24 of "Ocular Muscles and Fusion," Adkinson gives us the laws of coordinated action of group muscles. "Each group contains three elements:

"(a) The Agonist, which performs the act.

"(b) The Antagonist, which undoes the work of the agonist.

"(c) The Synergists, which balance or guide both the agonists and antagonists in their action."

This group action seems to apply to most of the organs and functions of the human body. For example, we have the functions of convergence and accommodation balanced by fusion. The heart has the same sort of group muscles, etc.

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*An abridgment of the material presented before the American Academy of Optometry at Chicago, Ill., August 24, 1936.

DEFINITION OF CONVERGENCE AND ITS EXPECTEDS

By convergence, as we understand the term, is meant the power of directing and holding the visual lines or axes of the two eyes toward a single point. It is the first step in the visual act of single binocular vision and acts much the same as a range finder, moving the two eyes into proper position for action. This is accomplished by the action of the lateral rectus muscles assisted and guided by the other extra-ocular muscles. The function of convergence is to always maintain single binocular vision at all distances.

Convergence is a voluntary action and is both conscious and subconscious, being innervated principally by the third and fourth nerves, and is under the direct control of the mind.

On page 118 of the "Oculo-Refractive Cyclopedia and Dictionary" we find this quotation by Adkinson, "Convergence at the near point is always a condition of unstable equilibrium, in the sense that two antagonistic muscles hold the eyes temporarily in a precarious pose, *in virtue of a powerful fusion stimulus.*"

On page 119 we find these words by the same writer, "All prism measurements of positive convergence err, because they eliminate the factor of accommodation, which is a legitimate and *normal stimulus of convergence.*"

We measure convergence by moving a small object two to five millimeters in diameter toward the eyes until diplopia occurs. This is the measurement of the maximum convergence of a particular individual. Rule: to measure the prismatic effect of convergence, we take the pupillary distance in centimeters and multiply this by the fixation distance in meter angles. Exl. pupillary distance 6.0 centimeters, fixation point 13 inches, or 3 meter angles, or 18 prism diopters. However, for the purpose of this paper we are not so much interested in the total possible maximum convergence as we are in the *habitual convergence.*

We believe it is generally agreed that the average patient with a pupillary distance of 62 millimeters has in effect, roughly speaking, 20 prism diopters of habitual convergence at 13 inches; to be exact, 18.6 prism diopters.

SUPPORTING FUNCTIONS AND EXPECTEDS

Now, if we can analyze and measure the sources of support to convergence in producing these 20 prism diopters of convergence, we believe we will have made an important step in locating the fatigued or stressed functions of the single binocular visual act.

We believe we know of at least three sources of stimulation or support that are used to produce and maintain convergence at this point (13 inches); namely, the fusion, accommodative, and psychic functions. Now, we are interested in knowing the amount of support each of these functions is expected to render in this visual act, in other words, we are interested in the expecteds, or norms, of these functions.

After using this technique for some five years, we have been able to set up standards or expecteds that serve our purpose very nicely. These expecteds we set empirically as: Fusion, 8△; Accommodation, 8△; and Psychic, 4△. A fourth finding that will affect the psychic finding somewhat will be explained later.

DESCRIPTION OF TECHNIQUE AND ANALYSIS

We make the finding as follows: working with the fixation object at 13 inches (for this purpose we use our utility near point card with the 5 millimeter dot as the fixation object) we have before the patient's eyes approximately his habitual correction, if one has been worn. In this procedure we strive for relaxation or inhibition of those functions that have been producing results.

Let us first consider the stimulation or support from the fusion faculty to the convergence act, and its significance. We measure the effect produced by this faculty at 13 inches merely by disassociating the fusion faculty from the convergence act with prism base up or down (usually 6 P. D. is sufficient). The amount of support that fusion has been rendering to convergence is measured merely by measuring the phoria at this point, and the resultant phoria in prism diopters indicates the part that fusion was playing in the convergence act before disassociation. As before stated, we have found this amount normally to be approximately 8 prism diopters of exophoria.

If the amount is considerably below 8, say 3 or 4, or even 5 P.D., it would indicate that the fusion faculty was not carrying its share of the support or stimulation. If, however, we found this to be greatly more than 8, say 10 or more, it would indicate that the fusion faculty was being over-stimulated or carrying more than its share of support to convergence.

Next let us consider the support from the accommodative faculty and its significance. We mechanically inhibit all possible accommodation at this point by placing plus 3.00 spheres before each eye. This disassociates the support of accommodation from the convergence act. Again we measure the phoria or exophoria, and note the INCREASE. The increase should be approximately 8 prism diopters, for at this point these two functions, fusion and accommodation, should render approximately the same amount of support to convergence.

Now, if the increased phoria over and above that already revealed by the disassociation of fusion in the first step be greatly less than 8 prism diopters, it indicates to us that accommodation is not supplying enough energy or support to convergence. If the increased phoria is high, it indicates accommodation is supplying too much energy to the convergence act and is being burdened beyond the expected amount. Let us say, for example, that the first step revealed only 3 prism diopters of exophoria and the second step revealed an additional 12 diopters of exophoria. This would indicate to us that the accommodative faculty was carrying the greater share of the burden.

For the sake of explanation let us reverse these figures. Say that the first step revealed 12 prism diopters and the second step revealed only 3. This would indicate to us that the fusion faculty was carrying the greater share of support to convergence. The higher finding indicates the greater fatigue or stress. In these two illustrations we have only thus far revealed or accounted for 15 prism diopters of support or stimulation of the total 20 prism diopters that we knew to be in effect at the beginning of this procedure. This leaves us 5 prism diopters of support as yet unaccounted for.

Experience has taught us that we can rightly attribute this balance or remaining support to the psychic faculty. On page 34 of "Ocular Muscles and Fusion," Adkinson[2] has suggested the term "directional compliment." This may be a more direct term but to my mind is hardly as descriptive as the psychic compliment of psychic convergence.

At this point Drs. Shepard[1], Skeffington[5] and others, like to use a fourth step that they believe has an important significance. After the first two, fusion and accommodation, are disassociated, a pair of plus 1.00 spheres is placed before each eye giving us a total of plus 4.00. Again measure the increase as in the two previous steps, and again the increase in this step should not exceed 2 prism diopters. This seems to be the most constant of all findings. If the increase is above 2 prism diopters, the suggested indication is that the subjective finding is not correct. If a reversal is manifest, that is, if the phoria is decreased instead of the expected increase, the suggested indication is that the habitual brain pattern is being violated, thus causing a rebound. To state it another way, we might say that the extreme point of relaxation or inhibition in one direction had been reached and we get the stimulation from the opposite direction. This, of course, comes pretty close to Sherrington's law of reciprocal innervation discovered by him 43 years ago, page 281[4] where the agonist becomes the antagonist and vice-versa; or what I believe Dr. Louis Jaques would call the second dimension innervation. Our own personal experience in this matter is that these cases are at least quite rare.

It has been found in a number of cases when this test was applied to known active pathological conditions that the first two findings, fusion and accommodation, have been extremely low; usually not to exceed two or three prism diopters each, and the addition of the plus 1.00 over and above the plus 3.00 does not usually show any response.

When we find the psychic support low with the other functions practically normal, indications are that the coordination between the hand and eye movements have not been properly developed. Again when we find the psychic support high, we may conclude that the coordination sense between hand and eye has been very highly developed. We have found further in dealing with cases of squint or esotropia that when we get normal or high response from the accommodation support, the case is usually one of accommodative esotropia. When the accommodative support is exceedingly low, we can rest assured we have a more

difficult task before us. Usually this is another type case where the hand and eye movements and the coordination between the two must be well developed by orthoptic training, drawing, etc.

With the average patient around 60 years of age we find not infrequently that the fusion or the psychic functions seem to be the only support to convergence. This seems to be due to the continued lowering of the accommodative amplitude and support. Naturally as the amplitude is lowered there is less support for convergence from this source, consequently the support must come from the other functions, usually that of fusion. This is one of the few functions that seems to improve with age.

SUMMARY

These findings are made at 13 inches following the regular routine examination, and are known as No. 22 in our routine examination.

In summarizing these findings we can but repeat. Our record of the findings when completed will look something like this: 8/8/1/3, if the case is one that is practically normal, representing 1st, fusion support; 2nd, accommodative support; 3rd, latent errors; and 4th, psychic or directional support.

1. (a) From a physiological viewpoint, when the fusion support is low it indicates an accommodative strain, stress or fatigue.

(b) When the fusion support is high, it indicates convergence insufficiency being corrected by the fusion faculty.

2. (a) When the accommodative support is low it indicates inefficient or insufficient accommodation and the load is being carried by the other functions.

(b) When the accommodative support is high indications are that the accommodative faculty is being strained or fatigued.

(The support from 1 and 2, fusion and accommodation, should be about equal, the higher one indicating the one more strained or fatigued.)

3. When the 3rd number is high indications are that the subjective finding is not correct.

4. (a) When the psychic support is low it indicates a lack of coordination development between the hand and eye activities.

(b) When the psychic support is high it indicates a well developed (sometimes too well developed) coordination between the hand and eye activities.

In pathology all findings are usually low and unreliable.

These findings work beautifully as a check-test a few weeks after the preliminary examination.

Technique, A, B, C and D.

1st step: A. Disassociate fusion and measure resultant phoria at 13 inches. This indicates fusion support.

2nd step: B. Inhibit accommodation with plus 3.00 at 13 inches and measure the phoria. The INCREASED phoria indicates accommodation support.

3rd step: C. Add plus 1.00 to the plus 3.00 and again measure the phoria. This indicates condition of subjective finding.

4th step: D. Subtract total of above phorias from original 20 prism diopters. The remainder indicates psychic support.

CONCLUSIONS

This test or one similar was originated by Dr. Carl Shepard[1] and modified by us to meet our practical requirements. One of the important changes made by us was to change the calculation from meter angles to prism diopters. You will note that we do not use meter angles, nor do we split prism diopters in halves or quarters, for in routine practice we are interested only in finding indications that point to the stress or fatigue of the function or functions responsible for the trouble, that we may direct our efforts at once to the correction of these abnormalities.

These steps should indicate to us which functions should be innervated or stimulated, and which function should be inhibited or suppressed in order to equalize to the point of harmony these three great and important faculties of human vision.

In closing may we say that we realize that much of this paper is not orthodox. Much of it is empirical, but we plead with you not to criticize until you have first understood and used the technique on a sufficient number of cases to arrive at a sane and practical conclusion.

We deem this one of the most simple, definite, and accurate steps in our regular routine examination.

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A FEW SUGGESTIONS ON THE ARRANGEMENT AND CLASSIFICATION OF BOOKS IN THE PRIVATE OPTOMETRIC LIBRARY, TO FACILITATE REFERENCE WORK

Many optometrists have, since finishing college, gradually acquired sizable libraries. Among a number of my friends, for instance, will be found ocular libraries varying from 150 to 400 volumes. These books deal with both general and specific subjects relating to health and ocular phases of optometric work. The writer too, has gradually added to his collection of ocular and related writings until his library reached such proportions that at times reference work became difficult because material was either impossible to find or was overlooked entirely.

This made it necessary to study methods by which such omissions could be overcome. In the technical libraries of our colleges for instance, works are cross indexed in reference files, each general subject being first covered and then each specific subject being also covered on individual record cards which enables one to immediately find all sources of reference needed on any phase of the work. This is of course most efficient, and what one would call the ideal way of handling the problem, but it has

the one drawback that it requires so much time to put into effect and so much time to keep up to date that for the individual, it is simply out of the question to attempt.

Furthermore, this system of cross indexing all reference material is only really necessary in libraries which run into the thousands of volumes, many of which are wholly unknown to the person desiring information. To the individual who is searching among his own books, which he has purchased and read, such a file would entail work and expense far beyond its value. The individual, having once read and studied a volume has a general knowledge of what the volume contains when next it comes to hand, and therefore in the private library it is necessary only to arrange one's own familiar volumes, in such a manner that those books with similar content matter are all to be found in one place. While such a system of book arrangement is by no means as satisfactory as is a card reference file, it does serve the purpose and greatly assists one in finding material on any subject referred to. It is this arrangement of books in the private library of an optometrist that is the subject of this paper.

The first step in a study of this sort was to break down or classify the books found in an optometric library into certain arbitrary divisions. These divisions had to do with the particular subjects covered by the author of the work considered. In a limited specialty such as optometry this at first looked easy, but careful consideration of the subject along with several years of practice in the matter, finally indicates that if this break down is to be of value at all, at least twenty individual and separate classifications of ocular and refractive books must be made. When this has been done, and when a library has been divided into these twenty component parts, it then becomes a relatively simple matter, even when many books are considered, to find the volume or volumes which deal with the material under consideration at the time. The twenty portions just referred to, and which in the writer's judgment cover the field of ocular and optometric refractive work will now be considered.

(1) General Anatomy and Ocular Anatomy

In this first subdivision of an optometric library I suggest placing all texts dealing with either general anatomy or ocular anatomy. I have placed this group of books in the number one position, because I feel that in doing any form of health work a complete knowledge of all of the anatomical factors involved is of primary importance. Every optometrist should have at least several books which fall into this classification. From the standpoint of general anatomy the set of anatomical manuals by Cunningham[1] or the text on this same subject by Gray[2] is indicative of the type of reference book under consideration here. As far as ocular anatomy is concerned, I am referring to such standard works as those written by Brown and Zoethout,[3] Ketchum,[4] Coque[5] and Goldnamer.[6]

These fine books, or at least one or two of them should be at hand in every optometric office. I have mentioned but a few of the first class texts available in this first subdivision. There are many other fine works in addition to the above, but the fact remains that every library should contain several of the fine texts in this field.

(2) General Physiology

In the second subdivision of an optometric library, I suggest placing all works dealing with the important subject of general physiology. This subject belongs in this leading place because of the importance of the subject to optometrists. A knowledge of how and why the body functions is obviously of great value to those performing in one of the minor subdivisions of a health activity as do optometrists, and for this reason every optometric library should contain material developed by authorities in this field. To illustrate the type of text referred to here, we refer the reader to the writings of Burbaker[7] or Macleod and Seymour,[8] these being but two of the many important and well written texts which are available on general physiology.

(3) Physiological Optics

Physiological optics as a subject by itself, is a branch of general science, which on one hand, deals with the most abstract philosophic problems of the mind and vision, while on the other hand it also deals with the every day practical problems as they confront the optometrist in his refractive work. That the optometrist must have a practical working knowledge of physiological optics, to enable him to do his work, goes without saying, and therefore I have placed in the third subdivision of an optometric library the books dealing with this interesting and vital subject. Southall's translation of Helmholtz's classic in this division of ocular writings would of course occupy first place in any portion of a library dealing with physiological optics. This monumental work done in three volumes[9] is without a doubt the greatest single contribution to the literature of the science that has ever been made and every optometrist intrested in his own development, should, if he has not already done so, arrange if possible to secure this outstanding work. If this is impossible, his library should include the very good substitutes written by Tscherning[10] or Zoethout.[11] Both of these latter works are reasonable in cost and contain much material which should always be at hand for reference.

(4) General Neurology and Ocular Neurology

Inasmuch as optometry is one of the neurological sciences, the study and application of general and ocular neurology naturally occupies a very important and prominent place in the work of the optometrist.

Because of this fact, I have placed text books dealing with the subject of neurology in the fourth subdivision of an optometric library. This subdivision deals principally with the visual paths and centers; the oculomotor system; the trigeminal nerve; the labyrinth; the cerebellum and all of the normal, abnormal and subnormal neuro-psychological factors of vision. Into this portion of an optometrist's library should be found the works of Rasmussen,[12] Hum,[13] Jelliffe and White[14] and many others of a similar character, all of which do much towards improving our understanding of this fundamental optometric subject.

(5) General Refractive Techniques

In this fifth subdivision of an optometric library I have placed those many fine works dealing with the entire subject of ocular examinations. In this group will be found those books which cover the principles of refraction: the correction of the various anomalies of refraction: the accommodative convergence relationships and the clinical application of these matters, as well as the prescribing of optical material to take care of the needs of patients. Text books coverering this entire subject are now, and have been, of immense value to all optometrists. To mention but a few of the authors who have well developed this thesis let me mention Laurance,[15] Sheard,[16], Duke-Elder,[17], Lesser,[18] and Jaques and Crow.[19] These men, and a number of others have done much to advance our science to its present high level and every optometrist's library should contain its fair quota of these texts.

(6) Specific Diagnostic or Refractive Techniques

In every specialty are found men who devote a large amount of time and thought to some particular portion of the work. These men become specialists within the specialty and are able to speak with authority on the particular branch of the science to which they have devoted their energies. This is particularly true in the fields of refractive work where we find a large number of technical writers each developing some phase of the specialty. The sixth portion of an optometric library is devoted to books of this character. The first works of this kind appeared a number of years ago, and dealt with ophthalmoscopic diagnosis. Among the early classics on ophthalmoscopy were the works of Loring[20] and Frost,[21] which have been followed by many fine texts on this important subject down to the most recent, just off the press, by Atkinson.[22] Every optometrist should have at least one or two of the many books on this subject at hand for reference in his office and others for use in his study at home.

Another refractive subject upon which much of real value has been written is that of dynamic skiametry. These books too, belong in this sixth suggested subdivision of an optometric library, which should include among others, the works on this subject by Cross,[23] Sheard,[24]

Atkinson and Woll[25] and Pascal.[26] Ryer's[27] classic on ophthalmometry too, should be at hand, as should several of the writings on visual field charting. In this last mentioned division, the outstanding contributions of Traquair,[28] Peter[29] and Brombach[30] will be found to be well nigh indispensible. The aforementioned writings are, of course, but a few of the many outstanding works to be found in this subdivision of the library. Other specialists such as Feinbloom,[31] Luckiesh and Moss[32] and Taylor[33] have added much to our knowledge, and their contributions should also, with those of many others, be included in the section of the library dealing with specific portions of refractive science. This division of an optometric library should be very complete as the individual writers in this field have made great contributions to the development of all of our refractive techniques.

(7) Extra Ocular Muscles and Squint

No single portion of ocular work has had the attention that has been bestowed upon the convergence relationships by both medical and optometrical writers. The imballances of the extra ocular muscles have proven an interesting and fruitful source of study and investigation, and as an outgrowth of these individual pieces of research have come many fine text books dealing with this subject from both a refractive and a treatment standpoint. These works form the seventh suggested section of an optometrist's library. A section that is of the greatest importance and one which should be fully developed. A few of the optometrists who have made marked contributions in this work are Robinson,[34] Shepard and Mendelsohn,[35] Peckham,[36] Swann[37] and Higley.[38] Among the more recent ophthalmological writers who have also contributed much of value might be mentioned Wells,[39] Hazen,[40] Wilkinson,[41] Worth,[42] Stutterheim,[43] Cantonnet and Filliozat[44] and Peter.[45] One might also include in a section of a library such as this one or more of the old classics in this field such as written by Savage[46] if such can still be had. There are of course, many other fine modern works dealing with this subject by both optometrists and ophthalmologists, and every optometrist should not only have his full quota of these books, but should be constantly adding to them, as new work is done and as new techniques are suggested to improve our refractive and orthoptic work on the convergence-accommodative relationships.

(8) Mathematics and Physical Optics

The theory of optical phenomena also plays an important part in the work of the optometrist. The study of light itself, of reflection, refraction, absorption and dispersion of light, all have a vital bearing upon this science. The action of lenses; the mathematics and physics evolved in our work all mean much to the members of this profession. A study of the various spectra and the newer theories in this section of general science are all matters of which the practicing optometrist must

have a working knowledge, and therefore it is suggested that a section of an optometric library be set aside for books dealing with these subjects. Here too, there is a wealth of material. The writings of Southall,[47] Emsley and Swaine,[48] Alexander,[49] Laurance,[50] Wood[51] and Shrader[52] are typical of the scientific writings which should be an important part of every optometrist's library. And here, too, it is necessary to keep constantly abreast of the newer developments in the field. Science moves constantly forward. This is particularly true in the realm of optics and for this reason the works in this section of the library must be brought up to date from time to time, as research work adds to our knowledge of these important matters.

(9) Ocular Pathology

From the diagnostic standpoint it is of the greatest importance that the optometrist be thoroughly familiar with the newest developments in the field of ocular pathology and its early recognition. Not only must he be able to recognize all of the clinical signs of ocular disease but in addition to this he must be able to make most of the necessary tests to determine just when his refractive and orthoptic work is, or is not, to be of value to the patient. This requires that a certain portion of his time be spent in studying the newer diagnostic material as it is presented by various medical authorities, and for this reason it is suggested here, that a section of his library be devoted to books dealing with the diseases of the eye. To be sure, no optometrist is expected to buy all the books which are published in this field. But every optometrist should add to his library, at least one important book on this subject, every two or three years. By so doing, he will keep in touch with the newer and more advanced thinking, and at the same time refresh himself on diagnostic tests contantly in use in his office. The works of Berens,[53] Wurdemann,[54] Parsons,[55], May,[56] and Atkinson[57] are but a few of the splendid writings on ocular diagnosis and disease which will add much to the value of an optometric library.

(10) Illumination and Color Vision

Here are two subjects each having a minor and yet an important place in the thinking and in the practical work of the optometrist. The subjects are inter-related and frequently are found to be part of some larger visual problem, which has been referred to members of this profession for solution. This is particularly true in the fields of industrial vision and safety. While it is not necessary that the optometrist become an illuminating engineer, it is necessary in my estimation, that he have a good working knowledge of light and of proper methods of lighting. This is especially true as this pertains to the minimum levels of illumination standards already set for various types of visual work. It is also true as it refers to the optometrist's work in the field of ocular hygiene

as every eye specialist should have a good working knowledge of lighting arrangement, so as to protect the worker from unnecessary and harmful glare. A section of his library should therefore be set aside for books dealing with this interesting and essential subject, starting perhaps with some of the more general texts dealing with visible radiant energy, such as for instance, that recently published work by Sheard,[58] and then into the more specific works on lighting such as written by Cushing.[59]

The subject of color vision is also a part, as I have said, of this same section of our work and it therefore follows that a suggested section of an optometrist's library should also contain several books dealing with the various theories of color vision, as well as some authoritative material on the topic of color itself. A test of color vision is a part of every routine ocular examination and an understanding of some of the fundamentals of this subject is of course essential in an optometric practice. The writings of Houstoun,[60] Edridge-Green[61] and Luckiesh[62] are typical of many of the important scientific contributions which have been presented on the subject of color vision and color. Books of this character will, if carefully studied, add much value to the type of actual work done by the optometrist, as they will stimulate him to further serious thought on the technical scientific phases of his work.

(11) Hygiene and Diet

As professional people it is necessary for us at times, to give advice to patients on matters, which of themselves, are not essentially ocular, but which do have a bearing on the ocular problems we, as refractionists are attempting to solve. In other words, some of the ocular cases which come to us for assistance can only be helped by advising these patients on matters pertinent to some of the fundamental principles of right living. For this reason a section of this suggested library should be devoted to books dealing with various topics such as proper eating habits, correct posture, and all of the other phases of hygiene, both from a general as well as an ocular viewpoint. The writer is not suggesting that as optometrists, we invade the field of the general practitioner of medicine, but rather to supplement him, and encourage our patients to cooperate with him, so as to improve their general health status and in this way improve the manner in which we find their eyes functioning. There are a great many fine texts dealing with these subjects and I will mention only a few to illustrate the various types of books to which I am referring. The first is naturally that classic written by Woll.[63] Others are the texts written by Drummond,[64] Pakes and Nankivell[65] and the ocular work by Posey.[66] Each of these deal with a separate portion of this study and as an optometrist's interest in these matters broadens, so will this section of his library become enlarged.

(12) Physical Therapy and Blood Pressure

While the writer realizes that there is little connection between the

two subjects suggested as general headings for this section of an optometric library, he has placed them together in this section as they are still, in some quarters, regarded by optometrists as "extra-ocular" subjects, or subjects of which there is yet some question as to their value in general optometrical procedure. However, irrespective of where one might stand in regard to the use of these techniques, it seems to the writer rather essential that every optometrist at least know what developments are being made in the diagnostic and orthoptic divisions of our work, whether or not he himself wishes to include any or all of this work in his own practice. For this reason a section of this suggested optometric library deals with these subjects.

The portion of this section dealing with physical therapy might well include the A. M. A. Handbook on this subject[67] as well as the text by Kurtz[68] and Turrell.[69] There are many other fine works which will give the practitioner a factual background upon which to rest any of the techniques he may elect to use in conjunction with his prismatic and stereoscopic orthoptic training procedures.

The other portion of this section of an optometric library dealing with the use of the sphygmomanometer in optometrical diagnostic work, should without question include a copy of Wiseman's[70] outstanding book on this subject, if one can still be had. If not, there are many other good texts such as that written by Norris[71] and others. It is now twenty years since Wiseman first suggested the clinical use of blood pressure tests in ocular diagnostic work, and his prediction of the value of these findings has been more than substantiated in a large number of optometrist's offices. The subject is one which merits the attention of every conscientious optometrist and is one which should have a place in the library of every practitioner who is anxious to do the very best possible work.

(13) Scientific Instruments

Because of the nature of his work and the background he has in the field of optics the optometrist logically can and frequently does interest himself in the technical optical developments made in the allied fields of photography, astronomy and microscopy wherein optical principles play such important parts. For this reason a section of the optometric library is set aside for texts dealing with scientific instruments. In the field of microscopy the work of Gage[72] might be mentioned as an outstanding text. In astronomy and telescope making, the book written by Ingalls[73] plays an important role. In television optics, the work of Myers[74] is very complete and in photography one of the many good texts is that written by Mees.[75] These and innumerable other fine writings dealing with the optical principles of various scientific instruments, many of which are of interest to optometrists, and all stimulate a better appreciation of the scientific side of optics and the technical development

which is being made by the research workers in these auxiliary fields.

(14) Sociology, Jurisprudence, Regulation and History

In this fourteenth subdivision of an optometric library I am suggesting placing those optometric books covering the evolutionary background of the profession as well as reports dealing with the legal and educational development of the science. From a historical standpoint the work of Arrington[76] covers much of the early legislative history of optometry. The report of Todd[77] and the later report of Woll[78] reviews the advancement made in our educational centers, while the work of Folsom[79] and of Kiekenapp[80] give a factual background of the work now being done by our State Boards of Examiners in Optometry. These and other similar reports are of the greatest importance in evaluating the development of the profession and should be kept as a permanent part of all optometric libraries as they contain much statistical material of value.

(15) Year Books and Bound Volumes

No optometric library would be complete without a section devoted to the preservation of the technical professional Journals which serve the profession. These can be kept in their original covers or can be bound in annual volumes as desired, but complete files should be carefully preserved, as much of value in the profession's literature is presented in these various technical publications. In this same section should be included the annual reports of optometric societies, and the Year Books issued by optometric organizations which represent the scientific work of particular interest to all optometrists. A large number of these volumes have already appeared and their number is growing yearly. The annual volumes of the American Academy of Optometry,[81] the annual publication of Lectures[82] delivered before the convention of the A. O. A., and the New York State Optometric Association's Year Book,[83] are typical of the works which add much of lasting value to a library on ocular matters, and should be included wherever possible. Indivdual volumes also, such as the technical reports of special gatherings[84, 85] should also be included here, as they, too, frequently contain special data of value to all eye specialists. This entire section is of the greatest importance to the optometrist and is one which should be developed to the fullest.

(16) Reference Works, Encyclopedia, and Dictionaries

In this subdivision of an optometric library I suggest placing those particular reference books having a bearing upon ocular work and ocular writings. Dictionaries dealing with every portion of our specialty, the diagnostic, symptomatic, refractive and also from the unusual standpoint

of optometry and optics in applied physics. From the purely ocular refractive aspect of our work the text by Atkinson[86] is of particular value to optometrists. The dictionary compiled by Stedman[87] is also an outstanding medical text for which many uses can be found. The work of Wiseman[88] too, fulfills a very vital need in the study of ocular symptoms. This book is particularly well written and very much used as a reference text. And this brings me to Glazebrook's[89] monumental set of dictionaries which cover the entire field of applied physics. These works which provide the optometrist with such a wealth of authentic material conveniently arranged so that every subject is fully covered. All of these and many other similar reference books should have a prominent place in every optometric library as they will prove their worth in many ways. This section obviously would not be complete without the addition of a good English academic dictionary.

(17) General Science

Persons having a general background of the arts and sciences in addition to a thorough training in some particular vocation are generally considered to be well educated. In other words, a person cannot claim to be well educated solely on the basis of his knowledge of some one particular specialty. This is true irrespective of the fund of technical information he may have acquired in the particular branch of literature, science or art in which he may be specializing. It is not enough to know thoroughly one's own field, but in addition, one must, to be well informed, have at least an acquaintance with the progressive thought in other fields allied to, and adjacent with, one's own speicalty, as well as some fundamental basic knowledge of all of the other major arts and sciences.

The foregoing being true, it becomes obvious that a section of this suggested optometric library must be set aside for books which are non-optometric in character but which will do much to keep the optometrist abreast of the developments in various other fields of scientific endeavor, and which will in a sense, continue his education by broadening his mental horizons and thus do much towards rounding out his mental development and education. In any limited specialty there is always the danger that the practitioners become so absorbed in their own work that they become narrow and thus lose the ability to view problems as a whole, rather than from the limited view as seen through the eyes of their specialty alone.

For this reason, text books such as Hauber's[90] new work in the field of biology might well be included in an optometrist's library. In bacteriology, Tanner's[91] new book on micro-organisms might be added. Baldwin's[92] introduction to comparative biochemistry and Whitemore's[93] work in the field of organic chemistry will also add much value to this section of the library. In the field of educational psychology, Commins[94]

has written a text which many will find of interest while Whitney's[95] work on the elements of research lays the proper basic foundation for any one interested in doing experimental scientific work. These are a few of the new books in the field of general science. There are, of course, others, many dealing with branches of science not mentioned above. These scientific fields as well as the developments in the realm of literature and art should be included in the library as it is only by varying one's interest that one is able to keep mentally alert.

(18) Stereoscopic Studies of the Eye

Because of some of the very fine educational work done in developing numerous stereoscopic studies of ocular pathology I suggest setting aside a small portion of this optometric library for editions of these stereograms. The photographic plates, the drawings and paintings of such authors as Oatman,[96] Coque,[5] and Elschnig[97] are all works which have been executed with considerable skill and certainly add, in a peculiar way that nothing else can, to our understanding of ocular pathology. Fundus plates for instance take on a much different meaning when viewed, as are those of Oatman, through a stereoscope and the photographic studies of mounted sections of eyes as developed by Elschnig are as fine as can be made. These sets of stereoscopic illustrations have real value and at least one such collection should be included in every optometrist's library.

(19) Optical Materials and Laboratory Techniques

As a knowledge of optical materials, and how they are made, is essential to optometrists, a section of his library should be devoted to the technical writings which explain these things. Much special information regarding the manufacture of both frames and lenses is constantly being published, by the various makers of optical supplies and materials, and a file of these special monographs[98,99,100] should be collected. In addition to these, a number of books have been written dealing with various phases of both the manufacture and use of these products. To mention but a few of these let me refer to Sheard's[101] research on the value of ophthalmic glass of various kinds. Also the report of the Commission[102] which made an exhaustive study of gold-filled spectacle frame material, as well as that well written text by Von Rohr[103] which deals with the dispensing problems which arise when these products have been prescribed. Mention should also be made of the book on laboratory work by Johnsen, Weeks and Weller[104] as this text covers the newer laboratory processes used in the field of surfacing, edging and mounting lenses, as well as much useful information on frames and how to make the most of them. The entire section is one dealing with a practical phase of the optician's work which every optometrist should be familiar.

(20) Optometrical Economics

This vitally important matter is placed last in this subdivision of an optometric library, not because of its unimportance, but rather because so little value from a professional standpoint has been written about the subject. The outstanding work in this field is that splendid text, now out of print, by Wiseman.[105] This is a book written sixteen years ago and every word is just as applicable today as it was the day it was first published. His text deals with practice building from a professional standpoint, and thoroughly covers every major phase. Other important contributions to certain parts of the economic fabric of an optometric practice have been made by Hall[106] and the Better Vision Institute. [107] Mention also should be made of the text written by Rukeyser.[108] This latter book, while written primarily for physicians has much sound financial advice which applies equally well to all professional people. Here is a field in which our literature is somewhat lacking and one that needs much good cultivation. The profession needs a second edition of BUILDING OPTOMETRY, a second edition brought up to date in a few particulars, but essentially the same as the first fine publication. The profession needs other writings in this field as well, as much valuable and essential knowledge of practice building could be compiled which would serve all optometrists as useful guides.

This concludes a review of the twenty suggested sections into which large optometric libraries can be divided for ease in handling. Such a division is easy to make and will prove useful, not only from the standpoint of ease in reference work, but also in bringing home to the optometrist the weak points of his library, and thus encourage him to develop certain sections which have perhaps been ignored. Every section of the suggested subdivision is of importance to the optometrist and every section should have at least several well written works of value at hand. And this brings up another very important matter and that is, that no library is ever a finished thing. No matter how complete it might be today, unless one is constantly adding to it, it soon becomes obsolete. A library should not become a static thing but rather should be a dynamic living force in the practice of every optometrist. It can only be this if it is given the attention it requires, and if the books, once they are at hand are used. By dividing one's library into sections as herein suggested it enables the optometrist to use these books with a great deal of ease, heretofore lacking. The matter is one I strongly recommend to every practitioner, as it will enable him to get a large amount of enjoyment and good from his literary investment.

Carel C. Koch.

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SPECIAL REPORTS

OPTOMETRIC FEES*

Herbert S. Player, Opt.D.
Stockton, Calif.

Many optometrists with excellent professional training, practice in an ethical manner identical with that of other professions, such as medicine and dentistry. These men belong to professional societies, study at post-graduate clinics, keep apace of optometric research; they are truly professional men in every respect save one: the charging of professional fees.

It is generally accepted by the public that a professional man derives his income not from profits on merchandise but from fees for personal services. The amount of the fee is suited to the individual case

*Submitted for publication May 11, 1937.

according to the complexity of the work, the facilities required, and the time consumed. This is the custom of the doctor, the lawyer, the dentist, and other professional men.

When a client consults his attorney there is no consideration given to the amount of paper consumed in reports and briefs, nor is the wear on the office typewriter a factor in setting the fee. When a patient consults his physician the medical supplies used in the treatment are a minor consideration. The primary thought is always *services rendered*.

The person with visual discomfort seeks the services of an optometrist in whom he has confidence. This individual desires relief from his headache and other discomfort, and he desires to properly care for his precious sense of sight. What does he do when he gets out of the elevator and walks into the doctor's office? He probably does not truthfully say that he desires better vision.

He is very apt to tell the doctor that what he wants is a pair of glasses! And if he is of the great majority he asks how much it will cost.

Of course this question cannot be answered at once. It is as though a sick patient should walk into his physician's office with the question, "How much will it cost me to get well?" Before the question can be answered a great deal of work must be done.

In optometry, as in medicine, the diagnosis is the most important part of the treatment. Once the cause of the difficulty is determined the cure takes care of itself. This means that the eye-examination in optometry is much more important to the patient than are the glasses which are later prescribed. The glasses in themselves are worth nothing, may even be harmful, unless the prescription found through the examination is correct.

The reason the public still thinks of glasses instead of professional optometric services is that many years ago glasses could be bought as merchandise; knowledge concerning the human eye was limited. But during the past thirty years the science of caring for vision has developed more than in the previous thousand years. Now prominent universities and professional schools require four years of training in optometry.

In the modern practice of optometry the majority of eye-examinations necessitate an hour's time; often more than one examination is needed. After the examination the doctor must analyze the case and prescribe for the patient. Corrective treatment usually requires lenses or ocular exercises, perhaps both. The services of fitting lenses to the patient and making subsequent rechecks contribute to the amount of time consumed. Highly technical and accurate instruments are required in all optometric work.

Is it not logical that these professional services should deserve a suitable fee? Once the patient realizes that the doctor's services are much more important than any glasses, it is obvious that the services are what he pays for, and not the materials used.

Therefore, in my practice the policy has been adopted of giving to the patient his glasses at the actual cost of making the prescription in the optical laboratory. The fee for services is the sole factor of income.

In a typical case the invoice rendered the patient looks something like this:

June 13, 1937

MR. JOHN SMITH
Stockton, Calif.
PROFESSIONAL SERVICES RENDERED:

Examination, orthoptic training, etc.		$ 9.00
Optical Materials at Laboratory Cost:		
Frame	$3.10	
Precision Lenses	2.55	
Handling Charge	2.00	7.65
TOTAL		$16.65

To the patient this statement of costs is self-explanatory; he is also told that subsequent rechecks of his visual condition will be made without cost. An appointment is always on the book for each patient. When the time comes for a change of lenses the patient is advised that an examination is needed. Extra pairs of glasses, such as for driving, golf, cards, etc., are given to the patient at actual cost plus a moderate handling charge. This makes for more thorough correction of visual needs.

This logical plan of professional fees is fair and saves the patient money. The fees are openly explained, hence must be reasonable.

This plan seriously hinders the unscrupulous seller of glasses who advertises for customers in order to sell them glasses at a high price. Such racketeering cannot survive when the public knows the true cost of optical materials; the high profits necessary to such enterprises could not be obtained.

Take the profit out of glasses and optometry is raised to its rightful professional position. Charge only for professional services and there is no real competition. *Only I can render my services.*

The trend toward this logical plan of optometric fees is already being manifested. The alert optometrist will foresee the change and prepare for it.

Reasonable fees for services—and give the patient his glasses at actual cost!

DR. HERBERT S. PLAYER
802 BANK OF AMERICA BLDG.
STOCKTON, CALIF.

ABSTRACTS

SOME EYE OBSERVATIONS. H. W. Rayner. Eye, Ear, Nose and Throat Monthly. Vol. 15, No. 2, pp. 60-62. 1936.

This short paper deals with clinical observations as developed in making ocular examinations and as part of the Report Rayner claims that in observing one thousand ocular patients he found the following number of cases in which the appearance of reaction of the pupil was other than normal. In 13% of these cases the pupil was irregular in shape. In 7% of these cases the diameter of the pupil of one eye as compared with that of the other varied. In 10% of these cases the pupil had a sluggish reaction to light, and in 3% there was no reaction to light.

C. C. K.

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REMOTE POINT FOR VISUAL ACUITY TESTS. Frank G. Murphy. American Journal of Ophthalmology. Vol. 19, No. 2, pp. 151-152. 1936.

Automobile drivers and trainmen should have their distance visual acuity checked at a greater distance than the usual 20 feet claims Murphy who suggests that examiners so arrange their offices so that some time during the course of the subjective part of the refraction the patient's attention could be directed to the outline of a test object about seven feet in diameter and located a mile from the refraction room window. According to Murphy, changes should then be attempted in the correction so as to improve the acuity of vision at this working distance.

C. C. K.

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BOOK NOTICES

OPHTHALMOSCOPY, RETINOSCOPY AND REFRACTION. W. A. Fisher, M.D., F.A.C.S. Professor of Ophthalmology, Chicago Eye, Ear, Nose and Throat College. Fourth edition. Published by the H. G. Adair Printing Co., Chicago, Ill. 210 pages. 240 illustrations, 24 of which are in colors. Fabrikoid. $2. 1937.

This is the fourth edition of this work on ocular examination procedure and has been revised by the author in many ways so as to keep it abreast of modern developments particularly as they relate to newer pieces of refracting room equipment. The book opens with a lengthy section dealing with ophthalmoscopy in which the author treats the subject from the standpoint of, first, techniques and then diagnosis. His descriptions of both the direct and indirect methods of ophthalmoscopic examinations are very thorough and complete and the section includes a

number of colored fundus plates, similar to those in use in the Schematic Eye.

Following this section a number of chapters are devoted to various other examination procedures. The external ocular inspection, field charting, subjective work and retinoscopy are all covered, as are the various forms of specific refractive errors such as hyperopia, myopia, presbyopia and astigmia. These sections of the book are written for the student, and when considered in this light are very well done. Dynamic skiametry and the relationships between accommodation and convergence are not included, and this is to be regretted as Fisher writes well and chapters on these matters would add much to the value of this text.

The book closes with a new chapter on orthoptic training. This chapter is divided into two parts, each being a review of the work done by various specialists. The first section reviews the orthoptic treatment work done by ophthalmologists in various parts of the world and in America. The second section deals with the ocular therapeutic orthoptic measures employed by optometrists. This chapter is of considerable interest as the two types of procedures are compared side by side. In this last chapter all of the modern training equipment now in use by both professions are mentioned and their place in this type of ocular work is well described. C. C. K.

* * * * *

MEDICAL TREATMENT OF CATARACT. A. Edward Davis, M.D. Published by the F. A. Davis Co., 1914 Cherry St., Philadelphia, Pa. 161 pages. Cloth $3. 1937.

This author believes that senile cataract is preventable and the book is written to prove this point and also to give all eye specialists much needed advice in this highly technical field of preventive ocular work. Davis stresses the early recognition and treatment of the condition and it is at this point, particularly in the recognition and early diagnosis that the optometrist will find the material in text of value. To be sure, your reviewer is positive that the author is entirely misinformed as to the average optometrist's ability to make a diagnosis of cataract when viewing the interior of the eye with an ophthalmoscope when no mydriatic has been used. To an ophthalmologist who through years of experience in his ophthalmoscopic work always aided by a mydriatic, the thought of using an ophthalmoscope without first using the drug comes as rather a shock and seems perhaps to be an impossible task, yet to the optometrist who is schooled in using the ophthalmoscope without the drug, the task is, may I assure Davis, by no means impossible, though perhaps slightly more difficult than when the drug is instilled. However, this is a relatively unimportant point and only brought out here to correct, in future editions, the only outstanding misstatement in the book.

Davis believes that senile cataract is caused by toxemias produced by errors in metabolism of the entire system. In addition he feels that such matters as eyestrain, focal infections, and injurious radiant energy may also be contributing causes. These all, he believes are in a great measure either correctable or preventable and therefore it is the duty of all eye specialists to immediately attempt remedial measures as early as possible in every case of senile cataract encountered. He does not believe in the technique of waiting for the conditon to progress until sight is lost before attempting to correct the condition, and devotes a large portion of this text to the medical, refractive and dietary treatment of patients suffering from the early symptoms of senile cataract. In this portion of the book he reviews many suggested, but as yet unproven therapeutic measures, but does so with an open mind, giving credit to various ophthalmologists who advocate these numerous treatment procedures. This is a field which is more or less new to the average eye specialist who has been reluctant to attempt these treatment techniques and Davis feels this entire attitude to be a mistake.

From the optometric standpoint the book has much to recommend it. The chapters dealing with the etiology, diagnosis, symptoms and pathogenesis are splendid and supply a much needed want. Davis writes clearly and carries his readers along in a manner which makes this a text which is hard to put aside once started. His subject is important and he has covered it very well indeed, with but one exception, and that is the omission of the outstanding prophylactic work done in this field by the New York City optometrists, Hotaling and Ryer. It is hoped their important work in this field of cataract prevention will be included in future editions.

C. C. K.

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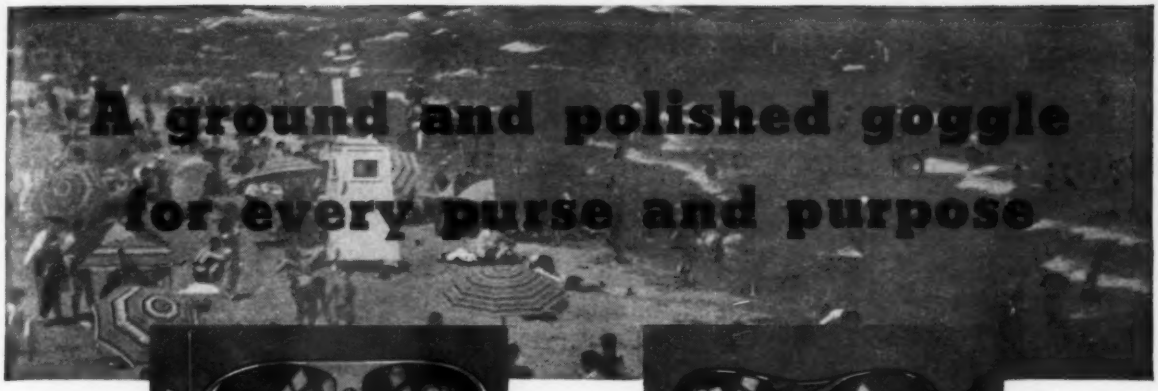
SENILE CATARACT. W. A. Fisher, M.D., F.A.C.S. Professor of Ophthalmology. Chicago Eye, Ear, Nose and Throat College. Third edition. Published by the H. G. Adair Printing Co., Chicago, Ill. 150 pages. 181 illustrations. Fabrikoid. $2. 1937.

This is a text largely devoted to various methods of operating on cases of senile cataract. Most of the work deals with these special surgical procedures, yet the pre- and post-operative techniques are also well covered. Six of the chapters were specially written for this work by the following ophthalmologists. The eminent French surgeon, Professor Ernst Fuchs who presents a short monograph on his capsulatomy and intracapsular operation. The famous Spanish ophthalmologist, Ignacio Barraquer who explains in some detail his now outstanding contribution to ophthalmic surgery, the Barraguer tecnique using a pneumatic forceps to express the lens. Also a chapter by Dr. H. T. Holland of India who describes his intracapsular operation and a similar chapter by Dr. J. D.

Wright who also gives his technique of the same operation in some detail. The Belgium specialist, Dr. Van Lint describes his extracapsular and intracapsular operations while Dr. Oscar B. Nugent has contributed a well written chapter on the refractive techniques necessary to correct these cases after the operation has been finished.

The author contributes several chapters, the first dealing with the intracapsular operative technique as developed by Arnold Knapp and another on the same operation this being done with the Elschnig technic. He also goes into some detail describing the capsulotomy operation as suggested by Homer Smith. Fisher also has much of value to offer in the portion of this work which deals with the choice of patient and the methods of correction employed to give these cases visual comfort after the operation is completed. These pages will be of interest to every optometrist and material of this kind should be available in every refracting room.

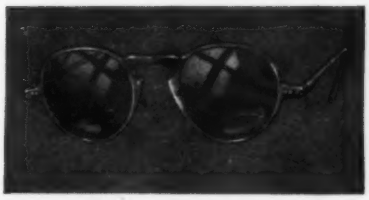
C. C. K.



The Ray-Ban—Made by Bausch & Lomb with ground and polished Ray-Ban Lenses, this is America's finest goggle. Ray-Ban Lenses are approved by Army, Navy and Transport fliers. Blond or flesh frames.

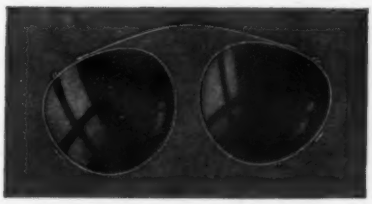
The Zephyr Streamline — Streamline styling in a popular sunglass for all around use. Smoke or Fieuzal ground and polished lenses; blond or flesh Zylonite frames. This is a popular priced glass.

The "R" 200 — Ground and polished smoke or filtray (Fieuzal) lenses; blond or flesh frame. Well designed and good looking.



The "R" 100 — Ground and polished, smoke or filtray (Fieuzal) lenses; blond or flesh Zylonite frame. An inexpensive goggle.

The Soft-Lite Over-Glas — The finest slip-over made; 1/10 12K gold filled; drop oval shape; No. 4 shade Soft-Lite Lenses.



Slip-Over Specs—Ground and polished Smoke or Fieuzal lenses; white or pink; round or drop eye. Every patient should have one.

And, of course, the famous Polaroid Goggles — The lenses in these goggles are made with Polaroid (a film-like material composed of countless minute flat crystals arranged parallel to each other) laminated between two pieces of glass. Polaroid glasses choose between diffused and specular light, removing the latter (reflected glare). Demi-Amber Ful-Vue Frame.

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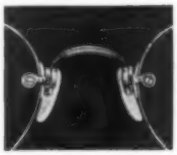

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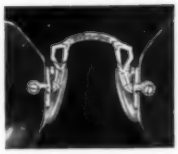

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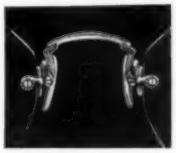

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